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MATHEMATICS RELAYS FOR HIGH SCHOOLS.

By Ernest H. Koch, Jr., and Thomas H. McCormick.

One of the most hopeful signs for the advancement of secondary school education is reflected in the increased attention which is being given to the content and instruction of the first year in the high schools. To those who are concerned with this work it is always a source of interest and profit to note and measure the development of pupils during this formative period.

Test 1. *Addition.*

(1)	(2)	(3)	(4)	(5)
869	494838	67949574	369231	168.29
675	489614	83357111	445170	1175.59
534	429868	23736625	233068	935.48
	793597	22165242	320122	27.61
		42776566	382428	872.29
		64111731	625552	1015.88
			717165	1322.37
			441314	537.48
			514685	170.23
			761336	540.62
				115.21
				696.66
				1006.33
				653.96
				177.87
				28.53
				262.71
				691.14
				104.12
				282.93

(6) Add horizontally $369 + 284 + 795 + 306 + 155 =$

It is a well-known fact that a test given to an entering class of high-school freshmen will show it woefully lacking in any sustained arithmetic operation. It is for this reason that every high-school course in mathematics should provide for a resumption of the elementary school drill for a period extending from five to ten weeks. The manner of presenting such a drill will depend upon the type of high-school course, the character of the work presented during the first year and also upon the attitude of the pupils and their teachers. It is considered advisable to learn the status of the class during the first day of school instead of wasting this time before the formal instruction is begun. It is suggested that you try Tests 1, 2, 3 and 4 upon your classes in order to determine their sustaining power in the four fundamental operations. An arbitrary but convenient basis for rating is to assign to each example a weight corresponding to its position in the set. Credit should not be given unless an example is completed without error. On this basis the maximum rating for six questions is 21. It is comparatively easy to arrange a set of examples so that the total operations in a particular example may be commensurate with its position in the set. The four tests may be given during one hour allowing a five-minute interval between tests.

Test 2. *Subtraction.*

$$\begin{array}{llllllll} (1) & 5782 & (2) & 46928743 & (3) & 356478912 & (4) & 46386721467 \\ & \underline{3798} & & \underline{35847865} & & \underline{99999999} & & \underline{34594677374} \end{array}$$

(5) From 4873925816 subtract 563872615 three times in succession.

Test 3. *Multiplication.*

(1) 62 × 36, (2) 848 × 759, (3) 78654 × 3.1416, (4) 86372417 × 624, (5) 75637 × 3 × 5 × 7, (6) 1425 lbs. meat @ 18¾ cents.

Test 4. *Division.*

(1) 365 ÷ 15, (2) 4638 ÷ 412, (3) 53896388208 ÷ 1147, (4) 120 ÷ 135, (5) 1.65 ÷ .9$\frac{1}{11}$.

Carry divisions to two decimal places.

Many high-school teachers realize that the pupil's reluctance to continue arithmetic is due to the failure to provide expedient methods for maintaining interest in the subject. It is the purpose of the authors to present from their experience a simple successful device which maintains the interest in arithmetic in a most unexpected manner and at the same time provides the most desirable incentives for accuracy and speed in the fundamental operations. This device is in the nature of a contest and is called a Mathematics Relay because it was first used as an event in an intellectual Three " R " Contest which was conducted like the usual athletic track meet.

The relay consists of four related parts presented in the following order: a continued addition, a continued subtraction, a continued multiplication, and a long division. It is performed by four boys who constitute a team. Each boy performs one of the operations and when he has finished the next boy follows him until all of the operations have been completed.

In order to have the entire class participate in a relay the class is divided into as many teams as there are multiples of four boys. The class teacher either selects or calls for volunteers who act as captains of teams. Each captain selects three other members to act with him as a team. If the classes exceed forty in number allow five members to a team in which case one boy in each team serves as an alternate.

All teams begin work simultaneously at the blackboards upon a signal from the teacher. The blackboards at the front of the room are adequate for this purpose and can be seen easily when the teacher is stationed at the rear of the room. The winning team is the one which finishes first with a correct answer. A member of a team may fail to do his assignment correctly and after two more vain attempts at a correct solution he is replaced by the alternate designated by the captain of the team. If the alternate fails in three attempts at the same assignment then that team forfeits its place in the contest. If the captain fails a new captain may be chosen and he in turn reorganizes his team.

At the beginning of the contest the captains write on the boards the subtrahend (S), and how many times it is to be used, the multipliers (M), and the divisors (D) similar to the following:

| S 98645, 5 times | M 6, 8, 9 | D 432 |

The captains then retire and send their respective adders to the blackboards and at a given signal they write two addends dictated by the teacher. Without any further direction and unaided he proceeds to form eight additional addends and finally sums the entire set of ten addends. The method of forming the additional addends is shown in the work below. The principle is to add two successive addends to form the one following, as shown below.

Addend (1)	34786	Dictated by the teacher.
Addend (2)	59301	Dictated by the teacher.
Addend (3)	94087	(1)+(2) added by the pupil.
Addend (4)	153388	(2)+(3) added by the pupil.
Addend (5)	247475	(3)+(4) added by the pupil.
Addend (6)	400863	(4)+(5) added by the pupil.
Addend (7)	648338	(5)+(6) added by the pupil.
Addend (8)	1049201	(6)+(7) added by the pupil.
Addend (9)	1697339	(7)+(8) added by the pupil.
Addend (10)	2746740	(8)+(9) added by the pupil.
Sum	7131718	added by the pupil.

A teacher's check which is not to be given to the pupil under any circumstance is to multiply the seventh addend by the number eleven.

When the teacher nods his head indicating a correct result the next boy of that team goes to the board and subtracts the subtrahend the required number of times from the previous boy's result.

Minuend	7131718	(previous sum).
Subtrahend	98645	
	7033073	first remainder.
Subtrahend	98645	
	6934428	second remainder.
Subtrahend	98645	
	6835783	third remainder.
Subtrahend	98645	
	6737138	fourth remainder.
Subtrahend	98645	
	6638493	final remainder.

When this work is correct the third boy goes to the board and does the required multiplication using the last boy's result as the multiplicand.

Multiplicand	6638493
First multiplier	6
	39830958
Second multiplier	8
	318647664
Third multiplier	9
Product	2867828976

Finally the last boy of the team goes to the board and divides the product obtained by his team mate by the required divisor written at the top of the board.

Divisor. Dividend.
432 | 2867828976
6638493 quotient.

That team which completes the work correctly in the least time is declared the winner and the champion of the class. A series of challenges follows and with the reduction in the time limit of contests the classes are able to form a challenging team to meet similar teams from other classes. By the process of elimination an all school team is chosen and this team represents the school in interannex or interschool contests.

The development of relay teams involves from five to ten minutes' drill daily during the arithmetic class period if there is one, otherwise it may be conducted by the official teacher or section officer during a study period. It needs no further comment to say that once relays are started the pupils will take care of themselves for practice whenever they may have the privilege to use blackboards before, between and after school sessions.

Incidental to these relays are the separate drills in the four fundamental operations, each of which provides opportunities for contests. They are important in themselves and become interesting because they are contributing factors to the relays.

Addition drills are always more interesting when they involve the formation of addends from two given addends and the subsequent summing of all the addends. It is wise to begin addition with numbers of the fourth order and gradually increase their magnitude until numbers of the ninth order are used. It is also desirable to limit the number of addends to six at the beginning and then rapidly increase this number to ten addends. For general class drills in addition the following order of difficulty is suggested. The number to the right of the two given addends indicates how many addends are to be used for the sum.

375	6	9437	6	88509	6	76549	10
246		8724		24763		28763	

Drills in subtraction require that a given subtrahend shall be used repeatedly and successively a definite number of times. It resembles a reverse of the process of addition described above excepting that the same operator is used.

Drills in multiplication involve two or more consecutive multiplications in which the multipliers are chosen from the nine digits. Variations are made by repeating the multipliers in different arrangements.

Drills in division involve a single divisor of low order. When the quotient is not integral it is required to express the remainder as a fraction in its lowest terms. Long division should be done directly without partition of the divisor. It is interesting to make the divisor the product of the multipliers of a previous multiplication example at the same time using the previous product as the new dividend.

If the teacher has a ready command of numbers he can use operators at random and obtain his answers for checking by short-cut methods.

An easy way to obviate the desire on the part of some pupils to cheat is to use a 6 × 9 yellow pad for drill work. After the sheets are distributed to the class each pupil is instructed to fold the paper into quarters. This provides eight spaces, each space being reserved for a single example. One space may be used for the date, name, class, time consumed in test, and the grade. Designate each of the eight spaces by number and dictate the operators for each example designating the space into which it is to be placed. When all the dictation has been made have the papers folded, exposing space one. At a given signal have the pupils blaze away but always keeping the papers folded to the space in which they are working. This makes a foolproof device which entirely eliminates opportunities for dishonest work. It should require less than a minute to distribute paper and dictate the examples. At first it will require about two minutes for each example, but this time may be cut in half after a week of drill and should reduce considerably but less rapidly after five weeks' drill. A relay such as is shown in this article should be completed within five minutes.

The following material has been used in the class rooms of the authors and will be found of great service, as the answers accompany each example. The examples in addition all involve ten addends. The subtraction examples all involve a repetition of the subtrahend five times. The separate multipliers are indicated by the commas which separate them.

Addition.

34786	54732	76592	76459	17809
59301	83196	31480	95467	37211
7131718	10331508	6982800	12606341	4254063

Subtraction.

7131718	10331508	6982800	12606341	4254063
98645	45678	78692	82821	54063
6638493	10103118	6589340	12192236	3983748

Multiplication.

6638493	10103118	6589340	12192236	3068994
6, 8, 9	5, 7, 9	4, 7, 6	7, 7, 7	8, 3, 5
2867828976	3182482170	1107009120	4181936948	368279280

Division.

432	2867828976	315	3182482170	672	107009120
	6638493		10103118		1647335
196	4181936948	144	368279280		
	21336413		2557495		

The following examples are appended for relay work but it should be noted that the examples listed above may be combined to make relay examples. In each case the addends are to be used ten times and the subtrahend is to be repeated five times.

Relay Examples.

47591	34758	74289	93897
24863	76828	35927	47095
4805449 sum.	8672224 sum.	7247471 sum.	9308695 sum.
78965 sub.	84628 sub.	83927 sub.	79317 sub.
4410634 rem.	8249084 rem.	6827836 rem.	8912110 rem.
7, 5, 9 mul.	4, 8, 7 mul.	7, 9, 4 mul.	8, 7, 6 mul.
1389349710 prod.	1847794816 prod.	1720614672 prod.	2994468960 prod.
630 div.	896 div.	336 div.	672 div.
2205317 quot.	2062271 quot.	5120877 quot.	4456055 quot.

The authors are not aware that the mathematics relay has been tried elsewhere before its introduction at the High School of Commerce in New York City. It will give the authors pleasure to learn the results of trials by other teachers. This device has demonstrated, to business men at three public exhibitions, that it is quite possible to train pupils in accuracy and speed in an effective and interesting manner and so they may continue to maintain the highest respect for the technique of computation.